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3. INSTRUMENT DATA EXPENDITURES FOR THE PURCHASE OF ACADEMIC SCIENTIFIC RESEARCH INSTRUMENTATION

3.1. Background[19]

The *National Survey of Academic Research Instruments and Instrumentation Needs* collects data for research instruments in six fields of science and engineering. This section of the report presents findings for instruments that were used for research in the biological sciences. The data for these instruments were collected from the principal investigators responsible for these instruments. These data differ from those presented in the preceding chapter which were provided by the department chairs and heads of facilities in the biological sciences.

The focus of this chapter is upon the analysis of three general sets of issues regarding research instruments in the biological sciences.

- **General Characteristics.** A major purpose of the instrumentation survey is to provide policy makers with basic descriptive data regarding the current inventory of research instruments. Thus, the first set of issues concerns the general characteristics of the Nation's current stock of research instruments. These issues include: the number of research instruments there are in the biological sciences; their age; their patterns of use by researchers, faculty, and graduate students; and the extent to which these instruments are used to conduct research in fields of science and engineering other than biology. This analysis is presented in section 3.2.

- **Financial Resources.** The second set of issues concerns the financial resources that have been used to purchase,[20] maintain, and repair these instruments. Of particular interest is the aggregate value of the Nation's stock of research instruments as well as the sources of funds used to purchase these instruments. The funds used to maintain and repair these instruments also are presented in this section. This analysis is presented in section 3.3.

- **Evaluation.** Finally, the instrumentation survey collects evaluative data regarding these research instruments. The principal investigators (PIs) were asked to evaluate the research status of their instruments (i.e., state-of-the-art, adequate, or inadequate)

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[19] Data for the purchase of research instrumentation are for the total current stock of in-service research instruments in the biological sciences. These instruments may have been purchased in any year, not just in the reference year for the survey (e.g., 1993). Data for the purchase of research instruments that were presented in Chapter 2 of this report refer only to instruments purchased during the reference year for the survey and not to the total stock of research instruments in biology.

[20] Data for the purchase of research instrumentation are for the total current stock of in-service research instruments in the biological sciences. These instruments may have been purchased in any year, not just in the reference year for the survey (e.g., 1993). Data for the purchase of research instruments that were presented in Chapter 2 of this report refer only to instruments purchased during the reference year for the survey and not to the total stock of research instruments in biology.

and their general working condition. They also were asked to assess whether or not the technical capabilities of the instruments met the needs of their users. Finally, they were asked to evaluate the adequacy of the maintenance and repair of these instruments. This analysis is presented in section 3.4.

3.1.1. Data Considerations

Data for research instruments in the biological sciences[21] have been collected since 1983 using the same general methodology and sampling plan, with two exceptions. First, in the current cycle of the instrumentation survey, the minimum purchase price criterion for the inclusion of a research instrument in the survey was raised from $10,000 to $20,000. The effect of this change was to significantly reduce the number of research instruments in biology that were eligible for inclusion in the survey.[22] In order to ensure that the longitudinal comparisons across the four cycles of the instrumentation survey remain consistent, data are presented only for those instruments with a purchase price of $20,000 or more.[23]

Second, beginning in 1989, data were collected for instruments with a purchase price of $1 million or more. For fields of science and engineering other than the biological sciences, many of these larger, more expensive research instruments were complex, integrated research systems known as supersystems. Examples of such systems include research vessels, telescopes, and wind tunnels. There are, however, extremely few of these systems in the biological sciences. Only two were reported in 1989, with a total value of $2 million, and none in 1993. Even though the effects of the supersystems upon the instrument data for the biological sciences are minimal, those tables that include data for supersystems are clearly marked in the sections that follow.

More important in the biological sciences are research instruments with a purchase price of $1 million or more that are not supersystems. In 1989, there were 14 research instruments with a purchase price of $1 million or more, not including supersystems. The total value of these systems was $23 million. In 1993, there were 23 such systems. Their total value was $33 million. Therefore, these systems are aggregated separately from those instruments that cost less than $1 million. The principal methodological issue posed by these systems is that no data were collected for them in 1983 and 1986. Therefore, aggregate totals for these two cycles of the instrumentation survey are not comparable with totals for 1989 and 1993. This only affects two tables in the following report. Each is clearly marked.

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[21] A research instrument was assigned to the field of science and engineering in which it was primarily used for research, as identified by the PI to whom the instrument was assigned.

[22] The effects of increasing the purchase price criterion from $10,000 to $20,000 were analyzed using data collected in Cycle III, before the purchase price criterion was changed. For all fields of science, 22 percent of all research instruments had a purchase price between $10,000 and $20,000. In biology, 29 percent of all research instruments had a purchase between $10,000 and $20,000.

[23] The procedures used to adjust the data in Cycles I, II, and III are presented in *National Survey of Academic Research Instruments and Instrumentation Needs, Methodology Report: 1993.*

3.1.2. Analytic Approach

In 1993, there were 20,978 pieces of equipment in the national inventory (or aggregate stock) of research instruments in the biological sciences. The total monetary value of these instruments was $1,150 million. For reporting purposes, each of these instruments has been categorized as one of the following five general types:

- **Computers and data handling equipment (Computers).** These instruments accounted for 10 percent of all research instruments in the biological sciences with a purchase price of at least $20,000. In terms of total value, they also accounted for 10 percent of the total value of the national inventory of research instruments in the biological sciences.

- **Chromatographs and spectrometers (Chromatographs).** This instrument type includes electron/auger/ion/scattering instruments, gas/liquid chromatographs, and electron spectroscopy/photo induced emission elemental analyzers. These accounted for 18 percent of all research instruments in the biological sciences with a purchase price of $20,000 or more. They also accounted for 22 percent of the total value of the national inventory of research instruments in the biological sciences.

- **Microscopy instruments (Microscopes).** Microscopes accounted for 17 percent of all research instruments in the biological sciences and 23 percent of the total value of research instruments in the biological sciences.

- **Bioanalytical instruments (Bioanalysis).** As might be expected, this was the largest general instrument category in the biological sciences in terms of total instruments, 44 percent. Instruments in this category include cell sorters/counters/cytometers, centrifuges, and growth/environmental chambers. Their total monetary value was 36 percent of the total value of all biological research instruments.

- **Other instruments.** This is a grouping of miscellaneous instruments that are not easily classified. The largest single type of "other" instruments in the biological sciences is lasers and optical instruments. Also included are robots and manufacturing machines, temperature/pressure control/measurement instruments, and major prototype instruments. This group contained 11 percent of all research instruments in the biological sciences and 9 percent of the total monetary value.

In addition, this analysis will present findings for:

- **Major subfields of biology** (biochemistry, cell biology/genetics, microbiology, pathology, pharmacology, physiology/biophysics, and other biological sciences);

- **Type of institution** (medical schools and colleges and universities);

- **Type of control** (public, private);

- **Instrument system price range** ($20,000 to $999,999 and $1 million or more).

This level of detail requires that only selected findings be presented. The analysis of the instruments generally will be limited to the five major categories of instruments since it is not feasible in a report of this type to describe each observation for every type of instrument, as well as for each of the seven subfields of biology, the two types of institutions, and the two price ranges. In general, one or two of the most significant findings from each table or figure will be presented.

3.2. General Characteristics of Research Instruments in the Biological Sciences

3.2.1. Introduction

The purpose of this chapter is to provide information relevant to three key policy issues regarding the Nation's stock of research instruments in 1993: the number of instruments used to conduct research in the biological sciences, the age of these instruments, and their patterns of use.

3.2.2. Sources of Data

At the start of the instrumentation survey, each participating institution was asked to provide an inventory of its research instruments, including each instrument's type, location, and date of purchase. From this information, the number of research instruments by type, field of science, price range, and age were determined. In addition, the PI for each instrument was asked to provide certain basic information about its usage patterns. Specifically, the PI was asked to provide a headcount of the number of faculty, graduate students, postdoctorates, and other researchers who used the instrument during the survey's reference period, 1993. The PI also was asked to identify the principal field of science and engineering in which the instrument was used for research and instruction as well as all other secondary fields in which the instrument was used.

3.2.3. Number and Types of Research Instruments in the Biological Sciences

In 1993, the 318 research universities and medical colleges that constitute the population for the instrumentation survey had 20,978 research instruments in the biological sciences with a purchase price of $20,000 or more. All but 23 of these instruments had a purchase price of less than $1 million dollars. (Table 6) The total number of biological science research instruments in 1993 increased from 17,659 in 1989 to 20,978 in 1993, a change of 19 percent. (Table 7)

Table 6. Number and percent of instrument systems, by field of biological science, type of institution, institutional control, system price range, and major type of instrument: 1993

Field of biological science, type of institution, institutional control, and system price range	Major type of instrument											
	All instruments		Computers and data handling instruments		Chromatographs and spectrometers		Microscopy instruments		Bioanalytical instruments		Other instruments	
	Total	Percent	Total	Percent	Total	Percent	Total	Percent	Total	Percent	Total	Percent
Total, all systems............	20,978	100%	2,126	100%	3,797	100%	3,611	100%	9,217	100%	2,227	100%
Research field:												
Biochemistry....................	6,739	32	503	24	2,131	56	41	1	3,750	41	315	14
Cell biology/genetics...........	3,756	18	194	9	146	4	1,586	44	1,454	16	376	17
Microbiology....................	2,654	13	37	2	482	13	228	6	1,820	20	87	4
Pathology.......................	431	2	86	4	30	1	174	5	56	1	85	4
Pharmacology....................	302	1	42	2	110	3	0	0	148	2	2	*
Physiology/biophysics...........	2,641	13	553	26	430	11	348	10	607	7	704	32
Other biology, general..........	4,455	21	712	34	468	12	1,236	34	1,382	15	657	30
Type of institution:												
Medical schools, total..........	10,926	52	1,002	47	1,698	45	1,960	54	5,057	55	1,209	54
Public........................	7,908	38	685	32	1,037	27	1,313	36	4,086	44	787	35
Private.......................	3,019	14	317	15	661	17	647	18	971	11	423	19
Colleges and universities, total.........	10,051	48	1,124	53	2,100	55	1,651	46	4,160	45	1,017	46
Public........................	6,989	33	664	31	1,504	40	1,045	29	3,117	34	658	30
Private.......................	3,062	15	459	22	595	16	606	17	1,042	11	359	16
System price range:												
$20,000-$999,999................	20,955	100	2,122	100	3,778	99	3,611	100	9,217	100	2,227	100
$1,000,000 or more..............	23	*	3	*	19	1	0	0	0	0	0	0

NOTES: Because of rounding, details may not add to totals.

KEY: * = less than 0.5 percent

SOURCE: Academic Research Instrumentation and Instrumentation Needs in the Biological Sciences, National Institutes of Health: 1994

Table 7. Trends in aggregate purchase price and median purchase price of academic research instruments in the biological sciences, by detailed type of instrument: 1989 and 1993

Detailed type of instrument	Number of systems			Aggregate purchase price (dollars in millions)		Median price per system (dollars in thousands)	
	1989	1993	Percent change	1989	1993	1989	1993
Total, all instruments	17,659	20,978	19%	$808	$1,150	$50	$50
Computers and data handling instruments	1,027	2,126	107	65	119	68	51
Computers/components costing:							
$1,000,000 and over	3	3	*	5	6	S	S
$500,000 - $999,999	11	7	-36	7	4	S	S
$50,000 - $499,999	395	583	48	36	59	94	98
$20,000 - $49,999	618	1,532	148	17	49	28	31
Chromatographs and spectrometers	4,195	3,797	-9	190	250	46	58
Chromatographs and elemental analyzers	1,636	1,993	22	55	71	30	33
Electron/auger/ion scattering	0	37	0	0	2	0	S
UV/visible/infrared spectrophotometer	1,122	715	-36	31	22	27	27
NMR/EPR spectrometer	136	184	35	35	79	273	441
X-ray diffraction systems	148	164	11	24	30	133	198
Other spectroscopy instruments	1,154	704	-39	45	46	37	70
Microscopy instruments	3,106	3,611	16	165	259	68	64
Electron microscopes	1,024	800	-22	96	121	104	152
Other microscopy instruments	2,081	2,811	35	69	138	30	48
Bioanalytical instruments	8,144	9,217	13	343	414	36	40
Cell sorters/counters, cytometers	121	223	84	22	36	202	137
Centrifuges and accessories	4,454	4,971	12	161	189	30	35
DNA/protein synthesizers/ sequencers/analyzers	1,077	1,242	15	97	99	88	84
Growth/environmental chambers	330	352	7	14	23	51	61
Scintillation/gamma radiation/counters/ detectors	2,162	2,428	12	49	67	22	24
Other instruments	1,188	2,227	88	45	109	37	44
Electronics instruments (cameras, etc.)	254	220	-13	9	11	37	60
Temperature/pressure control/ measurement instruments	516	27	-95	13	3	27	S
Lasers and optical instruments	78	163	109	5	16	S	96
Robots, manufacturing machines	17	124	629	-	5	S	S
Telescopes/astronomical	0	0	0	0	0	0	0
Nuclear reactors/nuclear science instrument systems	29	0	-100	3	0	S	0
Research vessels/planes/helicopters	0	2	0	0	-	0	S
Wind/wave/water/shock tunnels	0	0	0	0	0	0	0
Molecular/electron/ion beam systems	0	5	0	0	1	0	S
Major prototype systems	22	13	-41	6	3	S	S
Other, not elsewhere classified	271	1,674	518	8	71	29	36

NOTES: For 1989, this table includes data totaling $2 million for supersystems, which are large, integrated instrumentation systems/facilities.

This table, which includes data for two survey cycles, reflects a change in the determination of in-scope instruments in the survey. In 1989 the minimum purchase price for an instrument to be considered in-scope was $10,000; that minimum was changed to $20,000 in 1993. For consistency, data from the 1989 survey were standardized using the same minimum price criterion of $20,000 in constant 1993 dollars, according to the GDP implicit price deflator.

Because of rounding, details may not add to totals.

KEY: * = less than 0.5 percent (percent change in number of systems)
- = less than $500,000 (aggregate purchase price)
S = insufficient number of cases for analysis

SOURCE: Academic Research Instrumentation and Instrumentation Needs in the Biological Sciences, National Institutes of Health: 1994

Of these instruments in 1993, 44 percent were bioanalysis instruments such as cell sorters/counters/cytometers, centrifuges, and growth/environmental chambers. Chromatographs accounted for the second largest number of research instruments, 18 percent of the research instruments in the biological sciences. (Table 6)

The research instruments in the biological sciences were not evenly distributed across the subfields of biology. Thus, microscopes were heavily concentrated in cell biology (44 percent of all microscopes in the biological sciences were located in this subfield) while biochemistry had only 1 percent. On the other hand, biochemistry had 56 percent of all chromatographs while pathology had only 1 percent. (Table 6) For additional details about the distribution of research instruments by subfields of biology, see Table B-1 in Appendix A.

3.2.4. Average Age of the Research Instruments in the Biological Sciences

The average age of a research instrument in the biological sciences was 6.7 years in 1993. Overall, 16 percent of all research instruments had been acquired within the past 2 years at the time of the survey (1993) and 38 percent had been acquired within the past 4. (Table 8)

Table 8. Current age of academic research instruments in the biological sciences, by detailed type of instrument: 1993

Detailed type of instrument	Current age (percent of total systems)						Mean age (in years)
	Total	0 - 2 years	2 - 4 years	4 - 6 years	6 - 8 years	8 years	
Total, all instruments	100%	16%	22%	22%	15%	25%	6.7
Computers and data handling instruments	100	23	34	24	17	3	3.2
Computers/components costing:							
$1,000,000 and over	S	0	0	0	S	0	S
$500,000 - $999,999	S	0	S	0	S	0	S
$50,000 - $499,999	100	17	23	29	28	3	3.8
$20,000 - $49,999	100	25	39	22	12	3	3.0
Chromatographs and spectrometers	100	14	27	17	14	28	5.5
Chromatographs and elemental analyzers	100	13	24	22	20	21	5.0
Electron/auger/ion scattering	S	0	S	0	S	27	S
UV/visible/infrared spectrophotometer	100	9	21	8	8	54	7.0
NMR/EPR spectrometer	100	10	30	14	18	29	6.2
X-ray diffraction systems	100	37	23	22	12	6	3.2
Other spectroscopy instruments	100	19	38	13	6	24	5.4
Microscopy instruments	100	19	24	16	14	27	7.4
Electron microscopes	100	5	15	11	8	62	13.9
Other microscopy instruments	100	24	26	17	16	18	5.6
Bioanalytical instruments	100	12	15	26	16	31	8.5
Cell sorters/counters, cytometers	100	21	19	17	25	19	5.0
Centrifuges and accessories	100	12	16	28	16	29	7.6
DNA/protein synthesizers/sequencers/ analyzers	100	26	15	22	18	18	6.6
Growth/environmental chambers	100	21	17	31	17	14	5.4
Scintillation/gamma radiation/counters/ detectors	100	4	13	24	12	47	12.0
Other instruments	100	26	30	21	9	14	3.9
Electronics instruments (cameras, etc.)	100	9	6	51	7	27	5.7
Temperature/pressure control/ measurement instruments	S	0	S	0	0	S	S
Lasers and optical instruments	100	32	12	38	6	12	3.3
Robots, manufacturing machines	S	0	S	S	0	0	S
Telescopes/astronomical	0	0	0	0	0	0	0
Nuclear reactors/nuclear science instrument systems	0	0	0	0	0	0	0
Research vessels/planes/helicopters	S	0	S	0	0	0	S
Wind/wave/water/shock tunnels	0	0	0	0	0	0	0
Molecular/electron/ion beam systems	S	0	S	0	0	0	S
Major prototype systems	S	0	0	S	0	0	S
Other, not elsewhere classified	100	31	30	16	10	13	3.7

NOTES: Because of rounding, percents may not add to 100.

KEY: S = insufficient number of cases for analysis

SOURCE: Academic Research Instrumentation and Instrumentation Needs in the Biological Sciences, National Institutes of Health: 1994

Computers had the lowest average age of any instrument category, 3.2 years. Among computers, those with a purchase price of between $20,000 and $50,000 tended to be the most recently acquired; 25 percent had been acquired within the past 2 years at the time of the survey and 64 percent had been acquired within the past 4 years. Chromatographs also had a relatively low average age, 5.5 years. Within this category, x-ray diffraction systems were particularly new; 60 percent had been purchased within the past 4 years at the time of the survey and the average age of all such instruments was 3.2 years.

By contrast, bioanalysis instruments had the highest average age, 8.5 years. For one particular type of bioanalysis instrument, scintillation/gamma radiation/counters/detectors, almost half (47 percent) had been in use for 8 or more years. Similarly, 62 percent of all electron microscopes had been in use for 8 or more years and their average age was 13.9 years.

Research instruments in physiology/biophysics had the lowest average age (4.8 years) reflecting the relatively large number of computers and chromatographs that were used to conduct research in this area. (Table 9)

Table 9. Current age of academic research instruments in the biological sciences, by field of biological science, type of institution, institutional control, and system price range: 1993

Field of biological science, type of institution, institutional control, and system price range	Current age (percent of total systems)						Mean age (in years)
	Total	0 - 2 years	2 - 4 years	4 - 6 years	6 - 8 years	8 years	
Total, all systems	100%	16%	22%	22%	15%	25%	6.7
Research field:							
Biochemistry	100	12	23	22	14	28	6.3
Cell biology/genetics	100	21	21	16	19	24	6.6
Microbiology	100	10	11	31	13	35	12.5
Pathology	100	19	25	23	11	21	5.9
Pharmacology	100	16	29	19	19	17	5.0
Physiology/biophysics	100	23	24	20	16	17	4.8
Other biology, general	100	17	28	21	11	22	5.3
Type of institution:							
Medical schools, total	100	18	21	22	13	27	7.7
Public	100	14	19	24	12	30	9.1
Private	100	27	28	16	14	17	4.2
Colleges and universities, total	100	14	23	22	17	24	5.6
Public	100	12	23	22	17	26	5.7
Private	100	22	24	20	15	19	5.3
System price range:							
$20,000-$999,999	100	16	22	22	15	25	6.7
$1,000,000 or more	S	0	S	0	S	0	S

NOTES: Because of rounding, percents may not add to 100.

KEY: S = insufficient number of cases for analysis

SOURCE: Academic Research Instrumentation and Instrumentation Needs in the Biological Sciences, National Institutes of Health: 1994

The research instruments at colleges and universities were somewhat newer than those at medical schools. The mean age of the biological research instruments at colleges and universities was 5.6 years, which was below the mean average for all biological research instruments in 1993; the mean age for biological research instruments at medical colleges was 7.7 years. In both cases, the biological research instruments at public institutions were older than those at private institutions. (Table 9)

3.2.5. Patterns of Use of Research Instruments in the Biological Sciences

Research instruments in the biological sciences were used more intensively in 1993 than they were in 1989. In 1993, an average of 17.9 investigators used the biological research instruments. (Table B-2). The mean number of users per instrument in 1989 was 15.3. Of these users in 1993, most were graduate students or postdoctorates who were conducting research in the instrument's host academic unit, with an average of 8.7 users per instrument. In addition, an average of 3.8 faculty members of the host unit used each instrument to conduct research. (Table B-2)

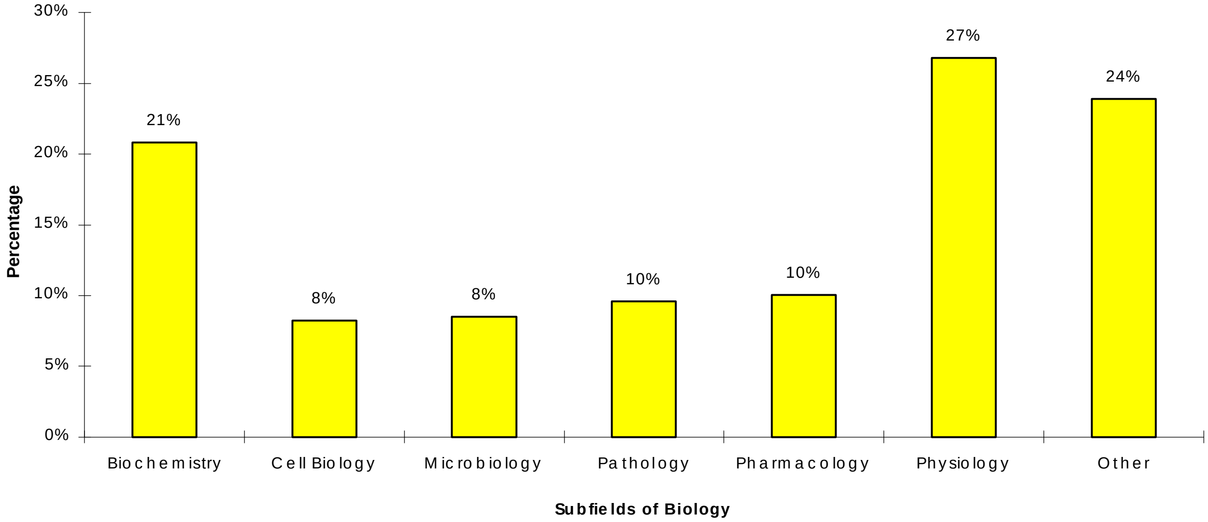
Each instrument had an average of 4.3 users from other departments or facilities within the host institution. This, in fact, was larger than the mean number of faculty users from within the instrument's host unit. However, the average number of users from outside the host institution was 0.7. (Table B-2)

Research instruments in the biological sciences were not used for research in other fields of S&E to the extent that other fields of S&E use their research instruments for such cross-disciplinary purposes. Overall, 39 percent of all research instruments in all fields of S&E were used to conduct research in more than one major field of science or engineering. However, only 18 percent of the research instruments in the biological sciences were used outside the biological sciences for purposes of research and instruction.[24]

The following analysis focuses upon three issues regarding these shared instruments. First, which of the major subfields within biology are most likely to share their research instruments with other major fields of science and engineering? As shown in Figure 5, instruments in physiology (27 percent), other biology (24 percent), and biochemistry (21 percent) are most likely to be used for research and instruction in a secondary major field of science and engineering.

[24] Unpublished NSF data

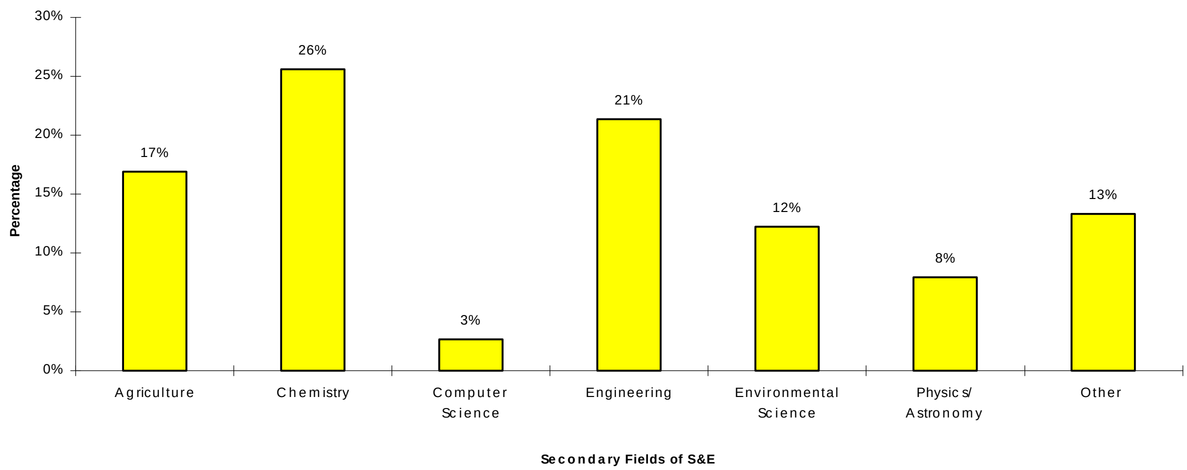
Figure 5. Percentage of biological instruments used for research in a secondary field of biology, by major subfields of biology: 1993



Source: Academic Research Instruments and Instrumentation Needs in the Biological Sciences: 1994

Next, with which of the major fields of science and engineering are the research instruments in biology most likely to be shared? Research instruments in biology as a whole are most commonly used in chemistry (26 percent) or in engineering (21 percent). (Figure 6)

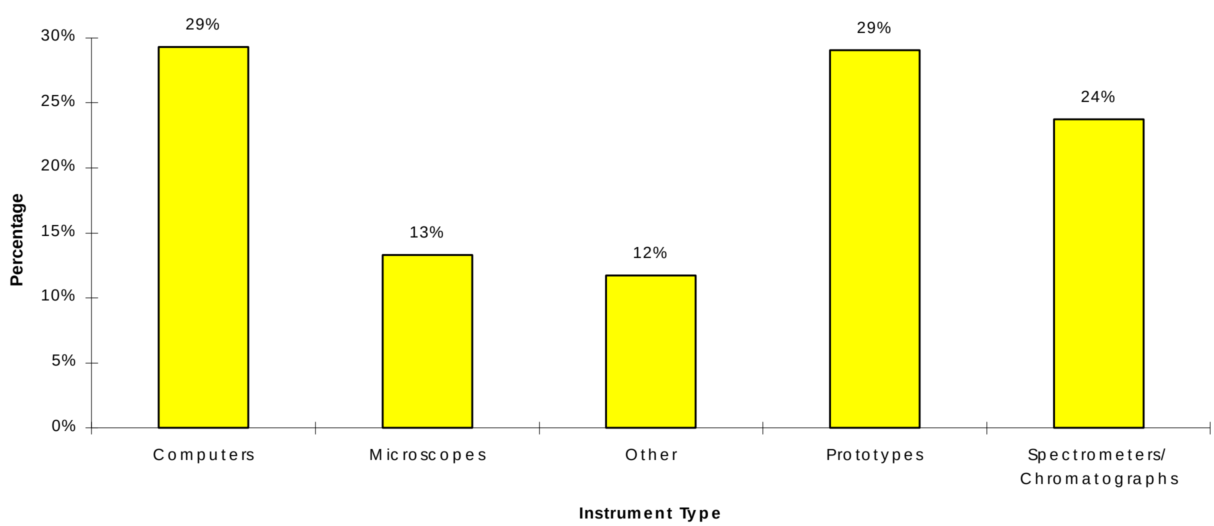
Figure 6. Percentage of biological instruments used for research in a secondary major field of S&E, by secondary fields of S&E: 1993



Source: Academic Research Instruments and Instrumentation Needs in the Biological Sciences: 1994

Finally, what types of research instruments are most commonly shared? Major prototypes and computers were the instruments most likely to be used by a researcher in a secondary field of S&E. As shown in Figure 7, 29 percent of the computers used in biology and 29 percent of the major prototypes were used for research in a secondary field of S&E.

Figure 7. Percentage of biological instruments used for research in a secondary field of S&E, by major type of instrument: 1993



Source: Academic Research Instruments and Instrumentation Needs in the Biological Sciences: 1994

3.3. Funding to Purchase, Maintain, and Repair the Aggregate Stock of Research Instruments in the Biological Sciences

3.3.1. Introduction

The purpose of this chapter is to analyze the financial resources that were used to purchase, maintain, and repair the aggregate stock of research instruments used in the biological sciences in 1993. Of particular interest is the monetary value of the Nation's current stock of research instruments, the sources of funds used to purchase these instruments, and the funds used to maintain and repair these instruments.

3.3.1.1. Sources of Data

As noted in the previous chapter, each participating institution was asked to provide an inventory of its S&E research instruments, including the purchase price of each. This inventory was used as the frame from which the sample of research instruments was selected. This sample of instruments was used to estimate the characteristics of the aggregate stock of research instruments in 1993, including its size, composition, and total cost.

The PI responsible for each research instrument in this sample then was asked to estimate both the source or sources of funds that were used to purchase or acquire the instrument, including all of its dedicated accessories, and the expenditures made for maintenance and repair (but not operation) of the instrument and its accessories during 1993. Note that the funds to purchase this aggregate stock were expended in various years, not just the survey reference year.

3.3.1.2. Aggregate Stock of Research Instruments

The findings presented in the following section refer to the funds used to purchase the aggregate stock of research instruments in the biological sciences. This aggregate stock includes all research instruments with a purchase price of $20,000 or more, regardless of the year in which they were purchased, that were being used to conduct research in the population of institutions that conducted $3 million or more in R&D during the survey reference year (i.e., 1983, 1986, 1989, and 1993). In 1993, this aggregate stock included 20,978 instruments that were used wholly or in part to conduct research in biology. (Table 6)

The estimates for the total cost of the aggregate stock of biological research instruments, and the estimates for the sources of funds used to purchase these research instruments, should not be confused with those presented in Chapter 2 of this report. The estimates in Chapter 2 were provided by unit-level respondents, rather than by the PI responsible for the research instrument, as in Chapter 3. The estimates in Chapter 2 for the total cost to purchase biological research instruments, and for the sources of the funds used to make these purchases, refer solely to those research instruments purchased in the survey reference year. The estimates in Chapter 3 for the purchase of the aggregate stock of biological research instruments, and for the sources of funds used to purchase these instruments, refer to any research instrument in use during the survey reference year, regardless of its year of purchase.

3.3.1.3. Total Cost and Location of the Aggregate Stock of Research Instruments in the Biological Sciences in 1993

The total cost of the aggregate stock of biological research instruments in 1993 was $1,150 million. (Table 10) As shown in Figure 8, 60 percent of the total cost was for instruments with a purchase price of less than $100 thousand. Only 3 percent of the total cost of the aggregate stock of research instruments was for those with a purchase price of $1 million or more. In terms of total aggregate cost, biochemistry had the single greatest amount of aggregate stock of biological research instruments, 30 percent. Other biology had the second greatest amount, 21 percent. (Figure 9)

Table 10. Aggregate purchase price and percent distribution of academic research instruments in the biological sciences, by field of biological science, type of institution, institutional control, system price range, and major type of instrument: 1993

[Dollars in millions]

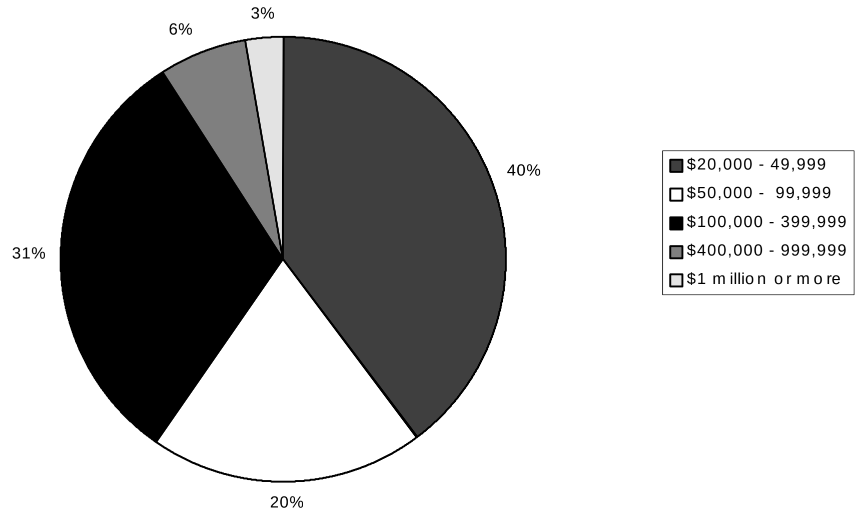
Field of biological science, type of institution, institutional control, and system price range	Major type of instrument											
	All instruments		Computers and data handling instruments		Chromatographs and spectrometers		Microscopy instruments		Bioanalytical instruments		Other instruments	
	Total	Percent	Total	Percent	Total	Percent	Total	Percent	Total	Percent	Total	Percent
Total, all systems	$1,150	100%	$119	10%	$250	22%	$259	23%	$414	36%	$109	9%
Research field:												
Biochemistry	355	100	26	7	128	36	3	1	183	52	16	4
Cell biology/genetics	207	100	14	7	6	3	121	59	51	25	15	7
Microbiology	133	100	3	2	14	11	15	11	96	72	5	3
Pathology	22	100	3	16	1	4	13	57	3	12	3	12
Pharmacology	18	100	3	14	9	52	0	0	6	31	-	2
Physiology/biophysics	173	100	29	17	58	34	22	13	21	12	42	24
Other biology, general	243	100	41	17	33	14	86	35	54	22	28	12
Type of institution:												
Medical schools, total	573	100	61	11	101	18	140	24	221	39	50	9
Public	379	100	35	9	49	13	88	23	175	46	33	9
Private	194	100	26	14	52	27	53	27	45	23	17	9
Colleges and universities, total	577	100	58	10	149	26	119	21	193	33	59	10
Public	394	100	39	10	98	25	83	21	140	36	34	9
Private	184	100	19	10	51	28	36	20	53	29	25	13
System price range:												
$20,000-$999,999	1,118	100	113	10	223	20	259	23	414	37	109	10
$1,000,000 or more	33	S	6	S	27	S	0	0	0	0	0	0

NOTES: Because of rounding, details may not add to totals.

KEY: - = less than $500,000
S = insufficient number of cases for analysis

SOURCE: Academic Research Instrumentation and Instrumentation Needs in the Biological Sciences, National Institutes of Health: 1994

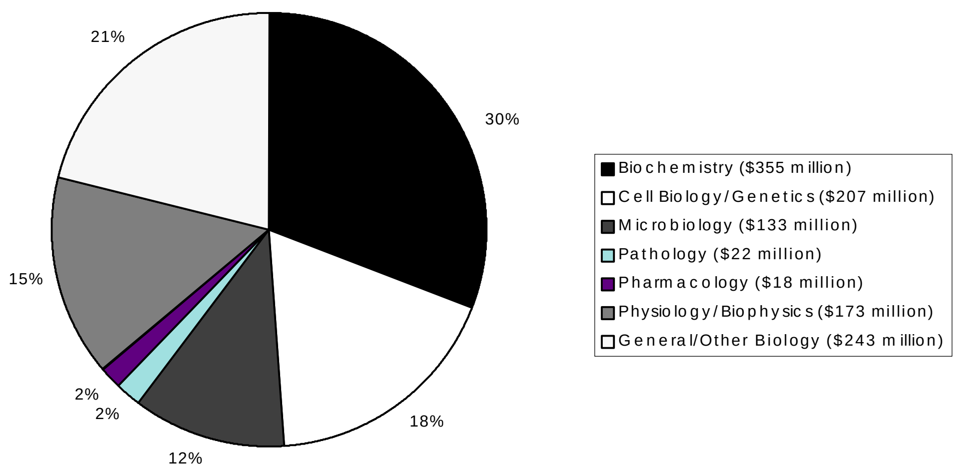
Figure 8. Distribution of aggregate purchase price of biological research instruments costing $20,000 or more per system, by price range: 1993



Note: Percents may not add to 100 due to rounding.
The aggregate purchase price for all biological research instruments in 1993 was $1,150 million.

Source: Academic Research Instruments and Instrumentation Needs in the Biological Sciences: 1994

Figure 9. Distribution of aggregate purchase price of biological research instruments costing $20,000 or more per system, by subfields of biology: 1993



Note: Percents may not add up to 100 due to rounding.
The aggregate purchase price for all biological research instruments in 1993 was $1,150 million.

Source: Academic Research Instruments and Instrumentation Needs in the Biological Sciences: 1994

Bioanalytical instruments were the largest category in the aggregate stock of biological research instruments, in terms of total cost. The total cost of these instruments was $414 million, 36 percent of the total cost of the aggregate stock of research instruments in biology in 1993. Microscopy instruments were the next largest category, containing 23 percent of the aggregate stock of research instruments and having a total cost of $259 million.

Biochemistry had the largest proportion of the total cost of the aggregate stock of research instruments. As shown in Table B-3, 30 percent of the total cost of the aggregate stock of biological research instruments was located in this subfield. The second largest amount of the total cost of research instruments was found in the other biological sciences (21 percent).

Additional details regarding the distribution of the aggregate stock of biological research instruments are shown in Figures 8 and 9.

3.3.2. Changes in the Distribution of the Number of Instruments and of the Total Cost of the Aggregate Stock of Research Instruments in Biology That Occurred Between 1989 and 1993

The total cost of the aggregate stock of research instruments in biology increased 42 percent between 1989 and 1993, from $806 million to $1,150 million. However, the median cost of a research instrument has remained the same, $50,000, for both time periods. (Table 7) This apparent contradiction is due to the uneven patterns of growth in the number and costs of different types of instruments, and among the various subfields of biology in which they are used.

3.3.2.1. Types of Instruments

The greatest increase in the aggregate stock of biological research instruments between 1989 and 1993 was for computers and data handling instruments. (Table 7) Overall, the number of these instruments increased by 107 percent during this period. The total purchase price increased by 83 percent, suggesting a shift to slightly less expensive computers. Indeed, the median purchase price of a computer dropped from $68,000 in 1989 to $51 thousand in 1993.

This shift in the composition of computers and data handling equipment is clearly shown in Table 7. The greatest increase in the number of computers was for those costing between $20,000 and $49,999. The number of these instruments increased by 148 percent, from 618 in 1989 to 1,532 in 1993. The total aggregate cost of these instruments increased by 188 percent, from $17 million in 1989 to $49 million in 1993.

The complement to this change was that the total number of the most expensive computers declined between 1989 and 1993. The number of computers and data handling instruments costing between $500,000 and $999,999 decreased by 36 percent (from 11 in 1989 to 7 in 1993). The aggregate cost of these instruments declined by 43 percent; but the number of computers with a purchase price of $1 million or more remained the same. (Table 7)

There was a significant increase both in the aggregate stock and in the total cost of two types of highly specialized instruments: robots/manufacturing machines, and lasers and optical instruments. Between 1989 and 1993, the aggregate stock of robots/manufacturing machines increased by 629 percent (from 17 to 124) and the total value of these instruments rose from considerably less than $1 million to $5 million. The amount of growth in number of lasers and optical instruments was not quite as great as for robots/manufacturing machines, but it was still quite large, 109 percent. The growth in the total aggregate value of these instruments increased by 220 percent, from $5 million in 1989 to $16 million in 1993. (Table 7)

The aggregate stock of chromatographs and spectrometers decreased between 1989 and 1993 by 9 percent. Within this major category of instruments, the greatest decrease was for other spectroscopy instruments, which declined by 39 percent; the aggregate costs of these instruments increased slightly (2 percent). In addition, the aggregate stock of UV/visible/infrared spectrophotometers declined by 36 percent. The total cost of these instruments declined by 29 percent. (Table 7)

3.3.2.2. Subfields of Biology

As shown in Table 11, some subfields, such as physiology/biophysics, other biology, and microbiology had significant growth in the total cost of their research instruments between 1989 and 1993: physiology/biophysics increased 128 percent (from $76 million to $173 million); other biology increased 103 percent (from $120 million to $243 million); and microbiology increased 96 percent ($68 million to $133 million). On the other hand, the total cost of the inventory of research instruments in pathology and pharmacology actually decreased between 1989 and 1993. In the case of pharmacology, the decrease was rather large, 53 percent (from $38 million to $18 million). (Table 11)

Table 11. Aggregate purchase price of instrument systems in the biological sciences, by field of biological science, type of institution, institutional control, and system price range: 1983 to 1993

[Dollars in millions]

Field of biological science, type of institution, institutional control, and system price range	Survey year			
	1983	1986	1989	1993
Total, all systems	$358	$543	$808	$1,150
Research field:				
Biochemistry	78	162	334	355
Cell biology/genetics	69	92	148	207
Microbiology	27	45	68	133
Pathology	22	32	24	22
Pharmacology	31	39	38	18
Physiology/biophysics	51	53	76	173
Other biology, general	79	121	120	243
Type of institution:				
Medical schools, total	218	308	467	573
Public	135	197	318	379
Private	83	112	148	194
Colleges and universities, total	140	235	341	577
Public	91	164	248	394
Private	49	71	93	184
System price range:				
$20,000-$999,999	358	543	785	1,118
$1,000,000 or more	0	0	23	33

NOTES: For 1989, this table includes data totaling $2 million for supersystems, which are large, integrated instrumentation systems/facilities.

This table, which includes data for all four survey cycles, reflects a change in the determination of in-scope instruments in the survey. In 1983 and 1986 data were collected only for instruments (and their corresponding units) with an original purchase price of $10,000–$999,999. In 1989 and 1993 coverage was expanded to include instruments with an original purchase price of $1,000,000 or more. In 1993, the minimum purchase price of an in-scope instrument was changed from $10,000 to $20,000. For consistency, data from the 1983, 1986, and 1989 surveys were standardized using the same minimum purchase price criterion of $20,000 in constant 1993 dollars, according to the GDP implicit price deflator. The $1,000,000 criterion was also standardized in constant 1993 dollars.

Because of rounding, details may not add to totals.

SOURCE: Academic Research Instrumentation and Instrumentation Needs in the Biological Sciences, National Institutes of Health: 1994

3.3.2.3.Other Factors

The growth of the total cost of the aggregate stock of biological research instruments in colleges and universities was greater than that for medical schools. Between 1989 and 1993, the total cost of the research instruments in colleges and universities grew by 69 percent. For medical colleges, the comparable figure was 23 percent. (Table 11) However, the total cost of the aggregate stock of research instruments for colleges and universities ($577 million) is approximately the same as for medical colleges ($573 million). 1993 was the first time since the instrumentation survey began in 1983 that the total cost of the aggregate stock of biological research instruments in colleges and universities exceeded that of the medical colleges.

3.3.3. Sources of Funds Used to Purchase the Aggregate Stock of Research Instruments in the Biological Sciences in 1993

The Federal government was the source of 45 percent of the cost of the aggregate stock of biological research instruments that were in use during 1993. The National Institutes of Health (NIH) invested $374 million dollars of the total cost of the aggregate stock of biological research instruments in service as of 1993. This was 33 percent of the total funds from all sources, making NIH the single largest source of Federal funds invested in these research instruments. The National Science Foundation (NSF) was the second largest Federal source of funds. NSF provided $92 million, 8 percent of the total cost of the aggregate stock of research instruments used to conduct biological research in 1993. (Tables 12 and 13)

Table 12. Distribution of aggregate purchase price of academic research instruments in the biological sciences, by source of funds: 1983 to 1993

[Percent of aggregate purchase price]

Source of funds	Survey year			
	1983	1986	1989	1993
Federal, total	51%	48%	53%	45%
National Science Foundation	9	9	8	8
National Institutes of Health	38	36	39	33
Department of Defense	*	1	3	1
Department of Energy	1	1	*	1
Other Federal sources	2	2	2	3
Non-Federal, total	49	52	47	55
Institution funds	34	36	31	35
State grant or appropriation	5	6	8	11
Industry	2	2	2	1
Other non-Federal sources[1]	8	8	6	7

[1] Includes private, nonprofit foundations, gifts/donations, and bonds

NOTES: This table does not include data for supersystems, which are large, integrated instrumentation systems/facilities.

This table, which includes data for all four survey cycles, reflects a change in the determination of in-scope instruments in the survey. In 1983 and 1986 data were collected only for instruments (and their corresponding units) with an original purchase price of $10,000-$999,999. In 1989 and 1993 coverage was expanded to include instruments with an original purchase price of $1,000,000 or more. In 1993, the minimum purchase price of an in-scope instrument was changed from $10,000 to $20,000. For consistency, data from the 1983, 1986, and 1989 surveys were standardized using the same minimum purchase price criterion of $20,000 in constant 1993 dollars, according to the GDP implicit price deflator. The $1,000,000 criterion was also standardized in constant 1993 dollars.

Because of rounding, percents may not add to 100.

KEY: * = less than 0.5 percent

SOURCE: Academic Research Instrumentation and Instrumentation Needs in the Biological Sciences, National Institutes of Health: 1994

Table 13. Distribution of aggregate purchase price of academic research instruments, by source of funds and field of biological science: 1989 and 1993

[Dollars in millions]

Source of funds	Field of biological science															
	All biological sciences		Biochemistry		Cell biology/ genetics		Microbiology		Pathology		Pharmacology		Physiology/ biophysics		Other biological sciences	
	1989	1993	1989	1993	1989	1993	1989	1993	1989	1993	1989	1993	1989	1993	1989	1993
Total..................	806	1,150	334	355	148	207	68	133	24	22	38	18	76	173	118	243
Federal, total	423	523	187	164	72	97	28	53	7	6	22	6	54	94	54	103
NSF	68	92	29	27	12	11	2	11	-	-	1	0	12	19	12	25
NIH..................	315	374	147	123	55	80	23	39	7	4	17	6	32	65	34	58
DOD.................	21	16	4	4	-	-	1	1	0	1	2	0	9	5	5	4
DOE.................	3	12	1	7	-	1	0	0	0	0	2	0	-	-	-	3
Other Federal...	16	29	6	4	4	4	2	3	0	0	-	0	-	4	3	13
Non-Federal, total.................	383	627	147	190	77	110	40	80	17	17	15	12	22	79	64	140
Institution funds	253	407	103	126	56	69	21	46	16	12	5	11	16	50	38	94
State government....	67	125	27	32	7	28	13	23	1	2	4	0	1	13	13	27
Industry............	15	11	2	2	3	1	2	-	0	1	4	0	-	1	4	5
Other non-Federal[1]	48	84	16	30	11	12	4	11	0	2	2	1	5	14	10	14

1 Includes private, nonprofit foundations, gifts/donations, and bonds

NOTES: This table does not include data for supersystems, which are large, integrated instrumentation systems/facilities.

This table, which includes data for two survey cycles, reflects a change in the determination of in-scope instruments in the survey. In 1989, the minimum purchase price for an instrument to be in-scope for the survey was $10,000; that minimum was changed to $20,000 in 1993. For consistency, data from the 1989 survey were standardized using the same minimum purchase price criterion of $20,000 in constant 1993 dollars, according to the GDP implicit price deflator.

Because of rounding, details may not add to totals.

KEY: - = less than $500,000

SOURCE: Academic Research Instrumentation and Instrumentation Needs in the Biological Sciences, National Institutes of Health: 1994

Overall, non-Federal sources provided $627 million (55 percent) of the total cost of the aggregate stock of biological research instruments that were in service in 1993. The largest amount of non-Federal funds was provided by the institutions themselves;[25] they provided $407 million (35 percent) for the purchase of the aggregate stock of biological research instruments that were in service in 1993. The second largest source of non-Federal funds was from State grants or appropriations, which provided 11 percent of the funds.

3.3.3.1. Funds Provided by NIH for the Aggregate Stock of Research Instruments in the Subfields of Biology in 1993

The largest investment of NIH funding for biological research instruments was in biochemistry, $123 million. This sum accounted for 33 percent of the total cost of the aggregate stock of biological research instruments that were funded by NIH. It also accounted for 35 percent of the

[25] Institutional funds generally come from one of four sources: indirect cost recovery from awards made by the Federal Government and other sources; State operating appropriations from general revenues; student tuition; and unrestricted gifts and income (e.g., endowments).

total cost of the aggregate stock of research instruments in biochemistry. The second largest investment by NIH was in cell biology/genetics. In 1993, the total cost of the aggregate stock of instruments in this subfield was $207 million, of which $80 million was provided by NIH. This was 21 percent of the total investment in biological research instruments funded by NIH ($315 million) and 39 percent of the total cost of the aggregate stock of research instruments in this subfield of biology in 1993 ($207 million). (Table 13)

3.3.3.2. Changes Among the Sources of Funds Since 1983

NIH has been the single largest Federal source of funds for the aggregate stock of biological research instruments since the survey began collecting biological science data in 1983. However, the proportion of funds provided by NIH has declined. In 1983, NIH funds accounted for 38 percent of the funds used to purchase the aggregate stock of instruments that were used to conduct biological research during that year. In 1993, this proportion was 33 percent.

This downward trend is similar to that for the Federal government as a whole. In 1983, the Federal government was the source of 51 percent of the funds used to purchase the aggregate stock of biological research instruments that were in use during that year. In 1993, the Federal government was the source of 45 percent of these funds. (Table 12) The NSF percentage in 1993 was 8 percent in 1993 and has remained essentially unchanged since the survey began in 1892–83 when it was 9 percent. (Table 12)

The proportion of non-Federal sources of the funds used to purchase the aggregate stock of biological research instruments has risen from 49 percent in 1983 to 55 percent in 1993. Among these non-Federal sources, institutional funds were the single largest source, providing 35 percent of the total. In addition, for the first time since the survey began in 1983, institutional sources in 1993 were the single largest source of funds for the purchase of the aggregate stock of biological research instruments and exceeded those provided by NIH. Support from the institutions has remained steady since 1983 when the institutions provided 34 percent of the funds used to purchase the aggregate stock of biological research instruments that were in service during that period. Finally, State sources of funds have steadily increased since 1983 when they accounted for 5 percent of the funds used to purchase the aggregate stock of biological research instruments. These sources accounted for 11 percent of the funds. (Table 12)

3.3.3.3. Changes in the Amount of Funds Provided by NIH for the Purchase of Research Instruments Since 1989

Although the relative funding of NIH for the purchase of the aggregate stock of biological research instruments declined from 39 percent in 1989 to 33 percent in 1993, the absolute amount of NIH funding increased. The amount of funds provided by NIH to purchase the aggregate stock of biological research increased by 19 percent between 1989 ($315 million) and 1993 ($374 million). (Table 13) Proportionately, the largest recipient of these funds was physiology/biophysics. In 1989, NIH provided $32 million of the total amount of money used to purchase the aggregate stock of biological research instruments then in service. In 1993, it provided $65 million, an increase of 103 percent. The second largest recipient was microbiology, whose funding increased by 70 percent between 1989 ($23 million) and 1993 ($39 million).

As shown in Table 13, the amount of NIH funds used to purchase the aggregate stock of research instruments declined for three subfields of biology between 1989 and 1993: pharmacology, pathology, and biochemistry. In terms of total funding support, the steepest decline was for biochemistry, which decreased from $147 million in 1989 to $123 million in 1993, a decline of 16 percent.

3.3.4. Expenditures to Maintain and Repair the Aggregate Stock of Research Instruments in the Biological Sciences

The annual expenditures to maintain and repair the aggregate stock of research instruments in biology in 1993 totaled $44 million.[26] This was 3.8 percent of the total expenditures for the purchase of the aggregate stock of biological research instruments that were in service in 1993. The median cost to maintain and repair each research instrument was $1,250. (Table 14)

[26] This estimate is based on data provided by the PI for each instrument included in the sample. In Chapter 2 of this report, the total maintenance and repair for research instruments was estimated to be $55 million in 1993. This estimate was based upon data provided by the heads of the departments and facilities in the biological sciences. In both cases, respondents were permitted to provide estimated data if actual data were not available. The latter estimate includes funds spent to maintain and repair instruments valued at less than $20,000. The former does not. Therefore, the estimates are not fully comparable.

Table 14. Total, mean, and median of annual expenditures for maintenance/repair (M/R) of academic research instruments in the biological sciences, and percent of aggregate purchase price, by detailed type of instrument: 1993

Detailed type of instrument	Annual expenditures for M/R (dollars in thousands)	Mean (dollars)	Median (dollars)	Annual M/R as a percent of aggregate purchase price
Total, all instruments	$43,775	$2,087	$1,250	3.8%
Computers and data handling instruments	4,594	2,161	1,500	3.9
Computers/components costing:				
$1,000,000 and over	121	S	S	S
$500,000 - $999,999	154	S	S	S
$50,000 - $499,999	2,152	3,694	2,700	3.6
$20,000 - $49,999	2,166	1,414	500	4.4
Chromatographs and spectrometers	6,721	1,770	1,000	2.7
Chromatographs and elemental analyzers	2,456	1,233	1,000	3.5
Electron/auger/ion scattering	82	S	S	S
UV/visible/infrared spectrophotometer	614	859	200	2.8
NMR/EPR spectrometer	1,260	6,831	5,000	1.6
X-ray diffraction systems	977	5,973	5,000	3.3
Other spectroscopy instruments	1,331	1,890	1,000	2.9
Microscopy instruments	9,600	2,659	1,000	3.7
Electron microscopes	6,888	8,606	9,044	5.7
Other microscopy instruments	2,713	965	300	2.0
Bioanalytical instruments	18,925	2,053	1,500	4.6
Cell sorters/counters, cytometers	1,190	5,348	5,000	3.4
Centrifuges and accessories	8,100	1,629	1,331	4.3
DNA/protein synthesizers/sequencers/analyzers	5,853	4,712	3,000	5.9
Growth/environmental chambers	554	1,573	900	2.4
Scintillation/gamma radiation/counters/detectors	3,227	1,329	1,400	4.8
Other instruments	3,935	1,767	650	3.6
Electronics instruments (cameras, etc.)	169	768	0	1.5
Temperature/pressure control/ measurement instruments	32	S	S	S
Lasers and optical instruments	672	4,122	1,000	4.1
Robots, manufacturing machines	327	S	S	S
Telescopes/astronomical	0	0	0	0
Nuclear reactors/nuclear science instrument systems	0	0	0	0
Research vessels/planes/helicopters	11	S	S	S
Wind/wave/water/shock tunnels	0	0	0	0
Molecular/electron/ion beam systems	11	S	S	S
Major prototype systems	64	S	S	S
Other, not elsewhere classified	2,649	1,583	500	3.7

NOTES: Because of rounding, details may not add to totals.

KEY: S = insufficient number of cases for analysis

SOURCE: Academic Research Instrumentation and Instrumentation Needs in the Biological Sciences, National Institutes of Health: 1994

Among the major types of research instruments, computers and bioanalytical instruments were the most costly to maintain. The median expenditures for both were $1,500 per instrument in 1993. (Table 14)

3.4. Status and Evaluation of Research Instruments in the Biological Sciences

3.4.1. Introduction

A major purpose of the instrumentation survey is to evaluate the technical capabilities of the Nation's stock of research instruments and their overall capability to assist investigators in the conduct of their research. Four general issues will be addressed in this chapter: the research status of the biological research instruments; the extent to which their technical capabilities met the needs of the researchers who used the instruments; the general working condition of these instruments; and the adequacy of the maintenance and repair support provided for these instruments in 1993.

3.4.1.1. Sources of Data

The PI for each instrument was asked to assess the research status of the research instrument in terms of a three-part evaluative scheme:

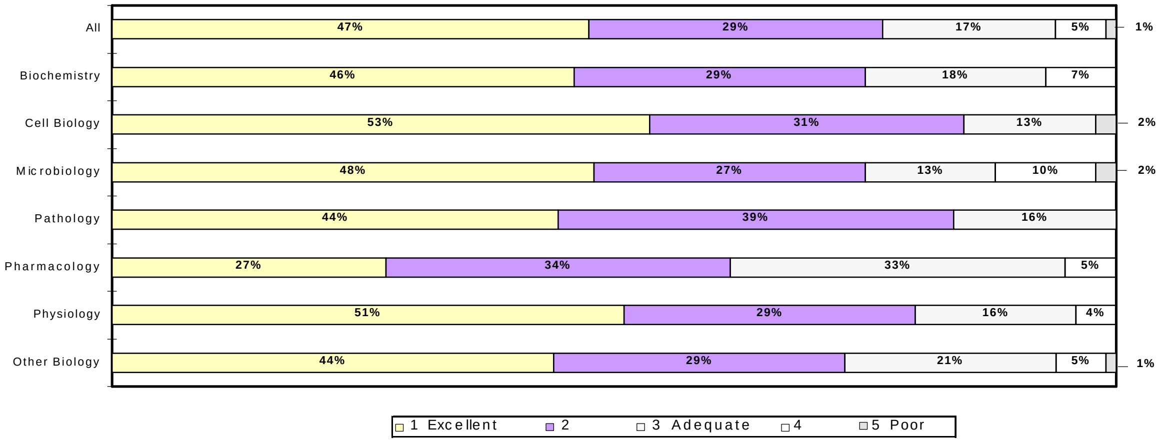
- state-of-the-art, the most highly developed and scientifically sophisticated equipment of its kind;
- not state-of-the-art, but adequate to meet the needs of researchers; or
- not state-of-the-art, inadequate to meet the needs of researchers in this department/facility.

The PI also was asked to assess three additional factors regarding the research instrument: its general working condition; the extent to which its technical capabilities met the needs of the research users; and the adequacy of the maintenance/repair received by the instrument during 1993. Each of the assessments was made using a five-point scale in which a score of 1 was excellent and a score of 5 was inadequate.

3.4.2. General Working Condition of Research Instruments in Biology in 1993

Overall, the general working condition of the biological research instruments was quite high in 1993: the working condition of 76 percent of these instruments was assessed as above adequate; only 6 percent were assessed as less than adequate. The general working condition of all of the instruments in pathology was assessed as at least adequate; 44 percent were reported to be excellent. In microbiology, 48 percent of the research instruments were reported to be in excellent working condition; the general working condition of 88 percent of the instruments in microbiology was reported to be adequate or better. (Figure 10)

Figure 10. General working condition of biological research instruments, by subfields of biology: 1993

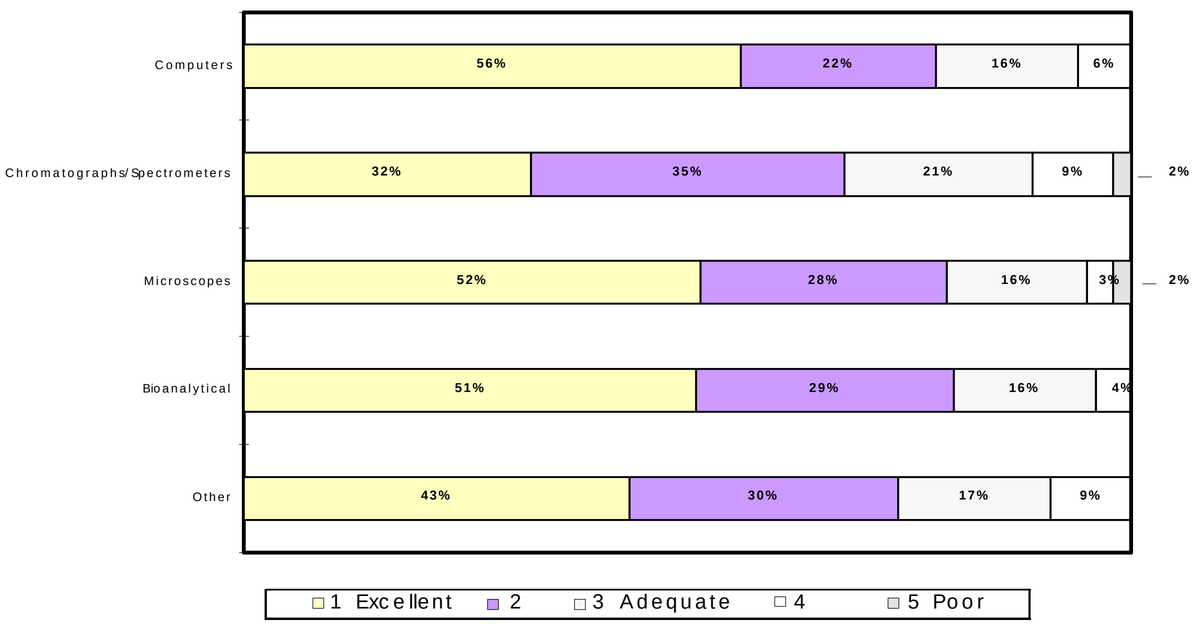


Note: Percents may not add up to 100 due to rounding.

Source: Academic Research Instruments and Instrumentation Needs in the Biological Sciences: 1994

Among instrument types, computers were assessed as being in the highest general working condition in 1993; 56 percent were reported as excellent; only 6 percent were assessed as being in less than adequate general working condition. (Figure 11)

Figure 11. General working condition of biological research instruments, by instrument type: 1993



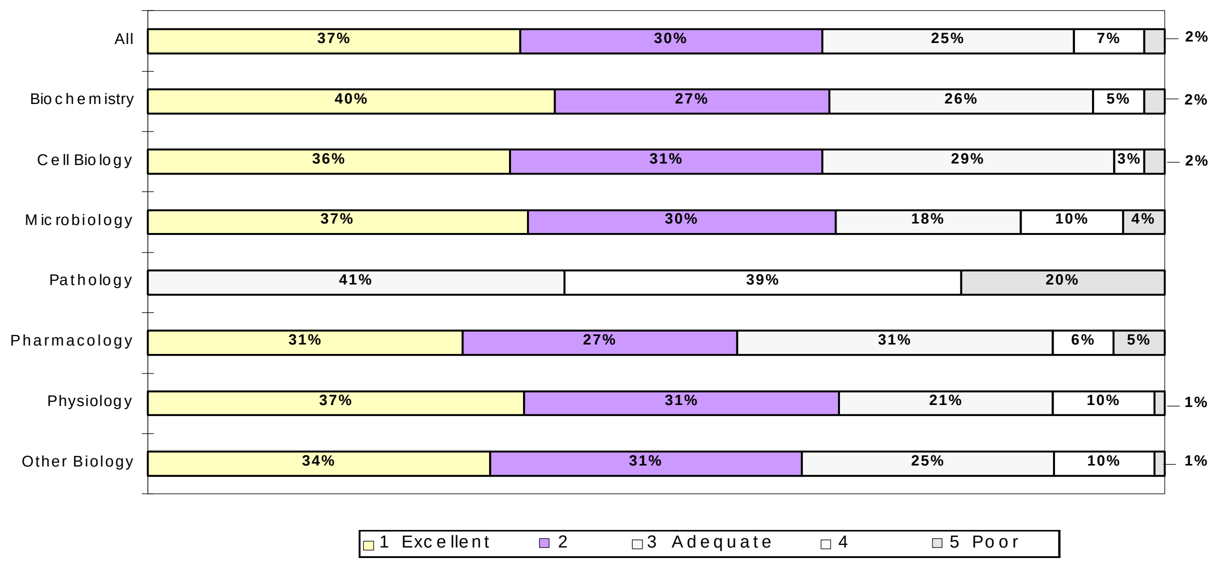
Note: Percents may not add up to 100 due to rounding.

Source: Academic Research Instruments and Instrumentation Needs in the Biological Sciences: 1994

3.4.3. Technical Capabilities of the Biological Research Instruments in 1993

Overall, 92 percent of the biological research instruments in 1993 had technical capabilities that were adequate to meet researchers' needs. In biochemistry, 93 percent of the research instruments had technical capabilities that were adequate to meet researchers' needs. In contrast, 59 percent of the instruments in pathology did not have adequate technical capabilities to meet the needs of the researchers who used them in 1993. (Figure 12)

Figure 12. Technical capability of biological research instruments to meet the needs of research users, by subfields of biology: 1993



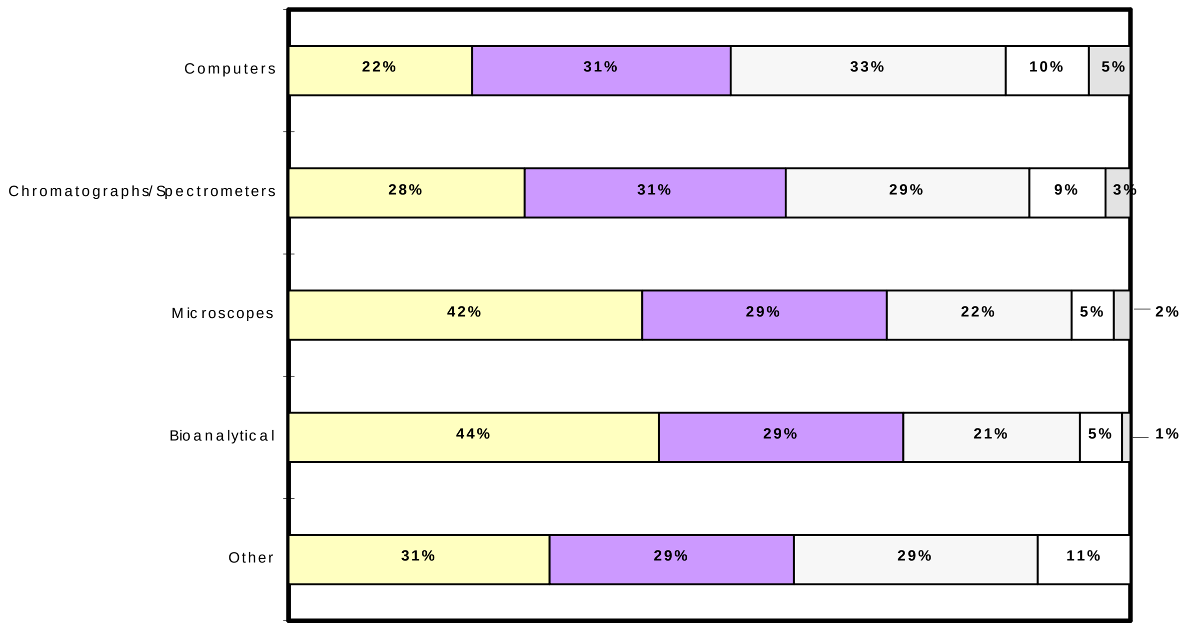
Note: Percents may not add up to 100 due to rounding.

Source: Academic Research Instruments and Instrumentation Needs in the Biological Sciences: 1994

Ninety-three percent of the microscopes were adequate to meet the needs of the researchers who used them in 1993; 42 percent of these instruments had excellent technical capabilities.

Eighty-six percent of the computers were adequate to meet researchers' needs; however, only 22 percent were rated as excellent. (Figure 13) This is somewhat surprising since the current stock of computers was relatively new. As noted above, computers had the lowest average age of any instrument category, 3.2 years. Among computers, those with a purchase price of less than $50,000 tended to be the most recently acquired; 25 percent had been acquired within the past 2 years at the time of the survey and 64 percent had been acquired within the past four. In addition, the greatest increase in the number of research instruments between 1989 and 1993 was for computers. (Table 7) These findings point to the difficulty of maintaining a stock of technically excellent computers at a time when the technology that underlies these instruments is changing and improving so rapidly.

Figure 13. Technical capability of biological research instruments to meet the needs of research users, by instrument type: 1993



Note: Percents may not add up to 100 due to rounding.

Source: Academic Research Instruments and Instrumentation Needs in the Biological Science: 1994

3.4.4. Assessments of the Research Status of Biological Research Instruments

As shown in Table 15, the principal investigators who use the biological research instruments assessed them as having a high level of technical excellence in 1993. Twenty-eight percent were assessed as state-of-the-art; 67 percent as adequate, and only 5 percent as inadequate to meet researchers' needs. The instruments in pathology were assessed as having the highest level of technical excellence among the subfields of biology: 39 percent of its research instruments were assessed as state-of-the-art, 61 percent as adequate, and none as inadequate. The instruments in microbiology were assessed as having the lowest level of technical excellence: 22 percent were assessed as state-of-the-art, 71 percent as adequate, and 8 percent as inadequate. (Table 15)

Table 15. Percent distribution of academic research instruments in the biological sciences, by field of biological science, type of institution, institutional control, system price range and rated research status: 1993

[Percent of systems]

Field of biological science, type of institution, institutional control, and system price range	Rated research status			
	All instruments	State-of-the-art	Adequate to meet researchers needs	Inadequate to meet researchers needs
Total, all systems	100%	28%	67%	5%
Research field:				
Biochemistry	100	29	66	5
Cell biology/genetics	100	31	66	3
Microbiology	100	22	71	8
Pathology	100	39	61	0
Pharmacology	100	31	60	9
Physiology/biophysics	100	29	69	2
Other biology, general	100	29	66	5
Type of institution:				
Medical schools, total	100	27	70	3
Public	100	26	71	3
Private	100	27	68	5
Colleges and universities, total	100	31	63	6
Public	100	27	66	6
Private	100	38	57	5
System price range:				
$20,000-$999,999	100	28	67	5
$1,000,000 or more	S	S	S	S

NOTES: Because of rounding, percents may not add to 100.

KEY: S = insufficient number of cases for analysis

SOURCE: Academic Research Instrumentation and Instrumentation Needs in the Biological Sciences, National Institutes of Health: 1994

The technical capabilities of biological research instruments were uniformly high across types of institutions and types of control. However, research instruments in private schools were somewhat more likely to be state-of-the-art than instruments in public schools. This difference was most pronounced in private colleges and universities, where 38 percent of the research instruments were state-of-the-art. In contrast, 27 percent of the instruments in public schools were state-of-the-art. (Table 16)

Table 16. Rated research status of academic research instruments in the biological sciences, by system rating, type of institution, institutional control, system price range, and major type of instrument: 1993

[Percent of systems]

System rating, type of institution, institutional control, and system price range	Major type of instrument					
	All instruments	Computers and data handling instruments	Chromato-graphs and spectro-meters	Microscopy instruments	Bioanalytical instruments	Other instruments
State-of-the-art[1]	28%	21%	29%	32%	26%	39%
Type of institution:						
Medical schools, total	27	14	23	35	25	36
Public	26	12	21	38	25	32
Private	27	20	26	28	22	42
Colleges and universities, total	31	27	33	28	28	42
Public	27	27	31	23	25	37
Private	38	27	38	38	37	51
System price range:						
$20,000-$999,999	28	21	29	32	26	39
$1,000,000 or more	S	0	S	0	0	0
Adequate to meet researchers needs[1]	67	67	66	62	71	59
Type of institution:						
Medical schools, total	70	74	72	60	74	64
Public	71	77	74	58	74	68
Private	68	66	69	63	76	57
Colleges and universities, total	63	60	61	65	68	53
Public	66	60	61	69	71	60
Private	57	61	59	58	59	42
System price range:						
$20,000-$999,999	67	67	66	62	71	59
$1,000,000 or more	S	S	S	0	0	0
Inadequate to meet researchers needs[1]	5	12	6	6	3	2
Type of institution:						
Medical schools, total	3	12	5	5	1	*
Public	3	11	5	4	1	0
Private	5	14	5	9	2	1
Colleges and universities, total	6	13	6	7	4	5
Public	6	13	7	9	4	3
Private	5	12	3	4	4	7
System price range:						
$20,000-$999,999	5	12	6	6	3	2
$1,000,000 or more	S	0	S	0	0	0

[1] The question was worded: "The research status of this equipment in FY 1993 was:
(1) State-of-the-art: the most highly developed and scientifically sophisticated equipment of its kind
(2) Not state-of-the-art, but adequate to meet the needs of researchers in this department/facility
(3) Not state-of-the-art; inadequate to meet the needs of researchers in this department/facility."

NOTES: The percents in this table are based on total number of instruments per major type of instrument.

Because of rounding, percents may not add to 100.

KEY: * = less than 0.5 percent
S = insufficient number of cases for analysis

SOURCE: Academic Research Instrumentation and Instrumentation Needs in the Biological Sciences, National Institutes of Health: 1994

Overall, among major instrument types, other instruments were assessed as having the highest level of technical excellence: 39 percent were assessed as state-of-the-art, 59 percent as adequate, and 2 percent as inadequate. Microscopy instruments were also assessed as having a very high level of technical excellence: 32 percent were assessed as state-of-the-art, 62 percent as adequate, and 6 percent as inadequate. (Table 16)

3.4.4.1. State-of-the-Art Research Instruments

As noted above, 28 percent of all biological research instruments were determined to be state-of-the-art by the PI responsible for the instrument. As shown in Table 17, the largest proportion of these state-of-the-art instruments (47 percent) was located among other instruments such as electronic instruments. The smallest proportion of state-of-the-art instruments (21 percent) was found among computers.

Table 17. Percent of instrument systems perceived as state-of-the-art for academic research in the biological sciences, by detailed type of instrument and current age of instrument: 1993

[Percent of systems]

Detailed type of instrument	Current age					
	Total	0 - 2 years	2 - 4 years	4 - 6 years	6 - 8 years	8 years
Total, all instruments[1]	28%	53%	37%	28%	23%	9%
Computers and data handling instruments	21	44	29	4	0	0
Computers/components costing:						
$1,000,000 and over	0	0	0	0	0	0
$500,000 - $999,999	S	0	S	0	0	0
$50,000 - $499,999	14	27	27	11	0	0
$20,000 - $49,999	24	49	29	0	0	0
Chromatographs and spectrometers	29	59	39	22	41	2
Chromatographs and elemental analyzers	30	60	48	10	40	3
Electron/auger/ion scattering	S	0	S	0	0	0
UV/visible/infrared spectrophotometer	20	S	S	0	S	3
NMR/EPR spectrometer	39	S	64	21	S	0
X-ray diffraction systems	33	S	35	S	S	0
Other spectroscopy instruments	29	65	15	69	38	0
Microscopy instruments	32	47	48	30	42	7
Electron microscopes	23	S	63	S	21	5
Other microscopy instruments	34	45	46	25	45	9
Bioanalytical instruments	26	61	34	31	17	10
Cell sorters/counters, cytometers	39	S	S	S	S	0
Centrifuges and accessories	28	59	40	30	13	13
DNA/protein synthesizers/sequencers/ analyzers	40	67	22	46	37	21
Growth/environmental chambers	42	S	S	S	S	0
Scintillation/gamma radiation/counters/ detectors	13	96	11	20	3	5
Other instruments	39	49	33	45	18	30
Electronics instruments (cameras, etc.)	47	S	S	S	0	0
Temperature/pressure control/ measurement instruments	S	0	S	0	0	0
Lasers and optical instruments	33	S	S	S	0	S
Robots, manufacturing machines	0	0	0	0	0	0
Telescopes/astronomical	0	0	0	0	0	0
Nuclear reactors/nuclear science instrument systems	0	0	0	0	0	0
Research vessels/ planes/helicopters	0	0	0	0	0	0
Wind/wave/water/shock tunnels	0	0	0	0	0	0
Molecular/electron/ion beam systems	S	0	S	0	0	0
Major prototype systems	0	0	0	0	0	0
Other, not elsewhere classified	41	47	36	47	20	41

[1] The questionnaire was worded: "State-of-the-art: the most highly developed and scientifically sophisticated equipment of its kind."

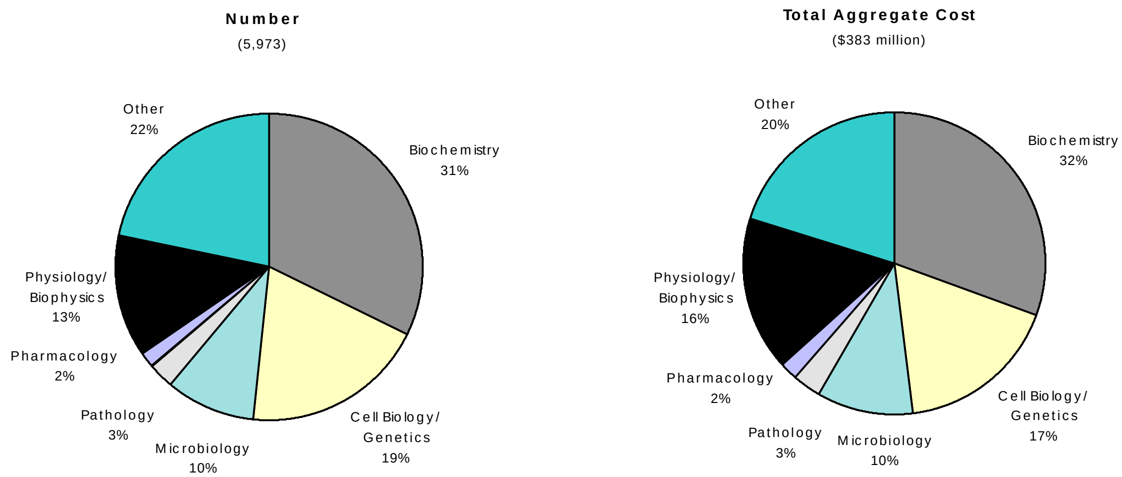
NOTES: The percents in this table are based on total responses per age group/instrument type.

KEY: S = insufficient number of cases for analysis

SOURCE: Academic Research Instrumentation and Instrumentation Needs in the Biological Sciences, National Institutes of Health: 1994

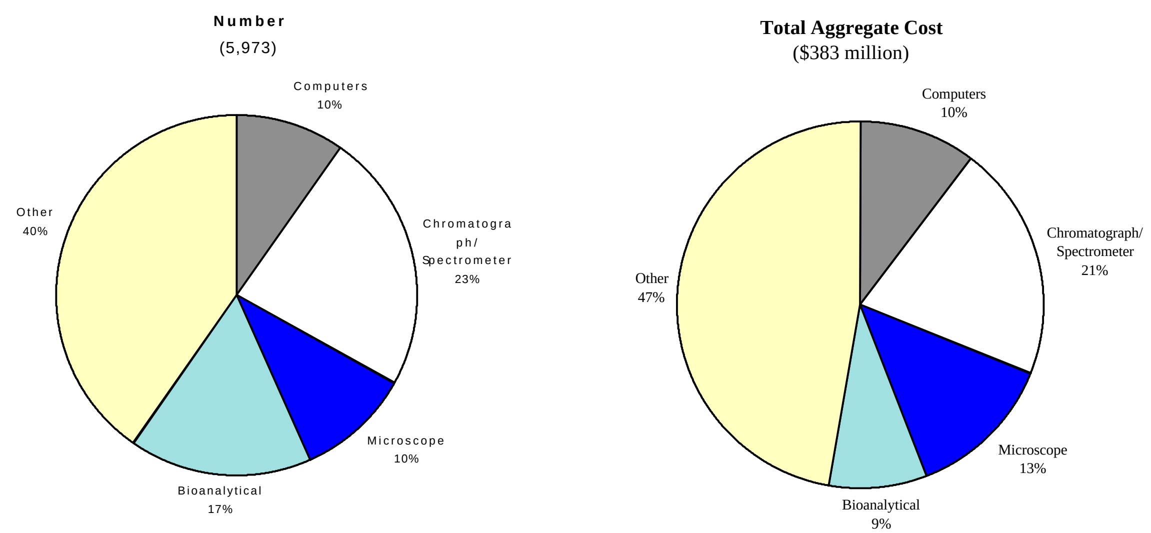
Biochemistry had the largest number of these state-of-the-art instruments (31 percent), while pharmacology had the fewest (3 percent). (Figure 14) In addition, most of these state-of-the-art instruments were classified as "other," which includes such equipment as electronic instruments and lasers. (Figure 15)

Figure 14. Number and total aggregate cost of state-of-the-art instruments, by major subfield of biology: 1993



Source: Academic Research Instruments and Instrumentation Needs in the Biological Sciences: 1994

Figure 15. Number and total aggregate cost of state-of-the-art biological research instruments, by instrument type: 1993



Source: Academic Research Instruments and Instrumentation Needs in the Biological Sciences: 1994

State-of-the-art research instruments in biology tended to be newer than biology research instruments as a whole. As noted above, the mean age of all research instruments in biology was 6.7 years in 1993. In addition, 16 percent of all research instruments had been acquired within the past 2 years at the time of the survey and 38 percent had been acquired within the past 4. By contrast, the mean age of state-of-the-art research instruments in biology was 5 years; 30 percent had been acquired within the past 2 years at the time of the survey, and 38 percent within the past 4 years.[27]

The relationship between the age of the instrument and its research status, however, was not linear. That is, state-of-the-art instruments were not always the newest. Table 17 shows the percentage of state-of-the-art instruments, by the type of instrument and the instrument's age. Thus, 28 percent of all research instruments in biology were assessed as state-of-the-art. For those instruments less than 2 years old, 53 percent were assessed as state-of-the-art; among instruments 2 to 4 years of age, 37 percent were judged state-of-the-art. (Table 17)

State-of-the-art computers tended to be relatively new: 44 percent of all computers that were purchased within 2 years of the survey's reference year (1993) were state-of-the-art; an additional 29 percent of the computers that were purchased during the previous 2 to 4 years were state-of-the-art. None of the computers that were purchased more than 6 years prior to 1993 were assessed as state-of-the-art.

Bioanalytical research instruments followed a similar pattern. Of all bioanalytical research instruments purchased within 2 years of the survey's reference year (1993), 61 percent were evaluated as state-of-the-art. The percentage evaluated as state-of-the-art steadily declined with the age of the instrument; of those instruments purchased 8 or more years prior to the 1993, only 10 percent were judged to be state-of-the-art.

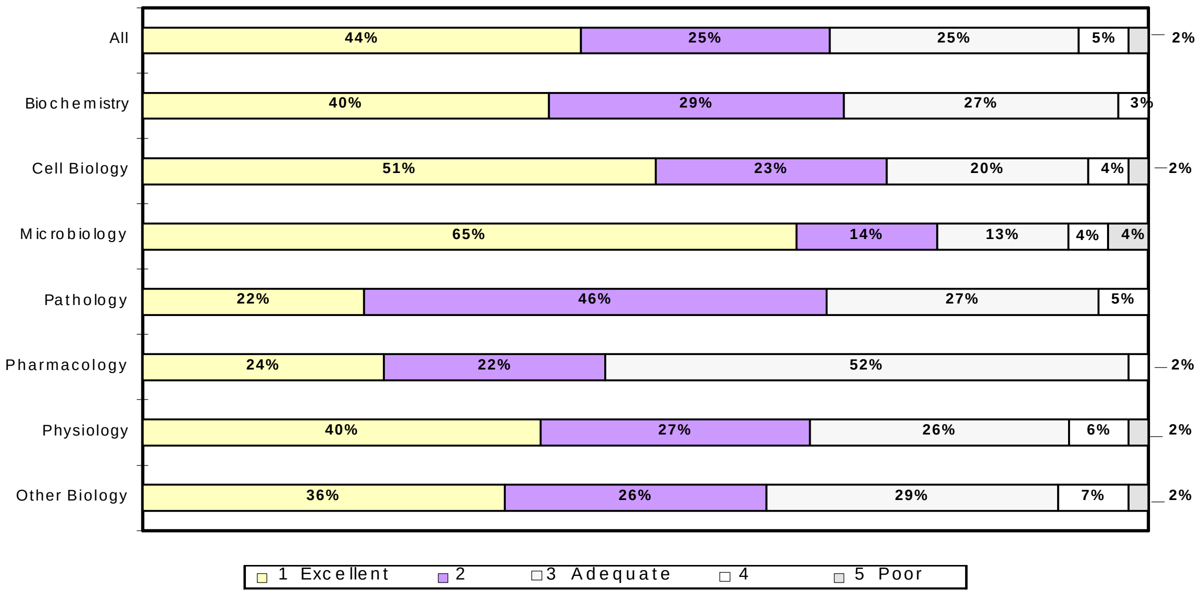
The pattern for other research instruments was less clear. For example, 47 percent of the microscopy instruments purchased between 1991 and 1993 were state-of-the-art. However, this proportion was essentially the same as for microscopy instruments purchased between 1991 and 1989, 48 percent of which were state-of-the-art. Indeed, a greater proportion of the microscopy instruments purchased between 1987 and 1985 were state-of-the-art (42 percent) than were the microscopy instruments purchased between 1989 and 1987 (30 percent). (Table 17)

3.4.5. Adequacy of the Maintenance/Repair Provided to Biological Research Instruments in 1993

Maintenance and repair support for the biological research instruments in 1993 was quite good. PIs reported that 44 percent of the biological research instruments received excellent maintenance and repair support during 1993. (Figure 16) Overall, 94 percent of these instruments received adequate or better maintenance and repair support.

[27] Unpublished NSF data

Figure 16. Adequacy of the maintenance/repair of biological research instruments, by major subfields of biology: 1993



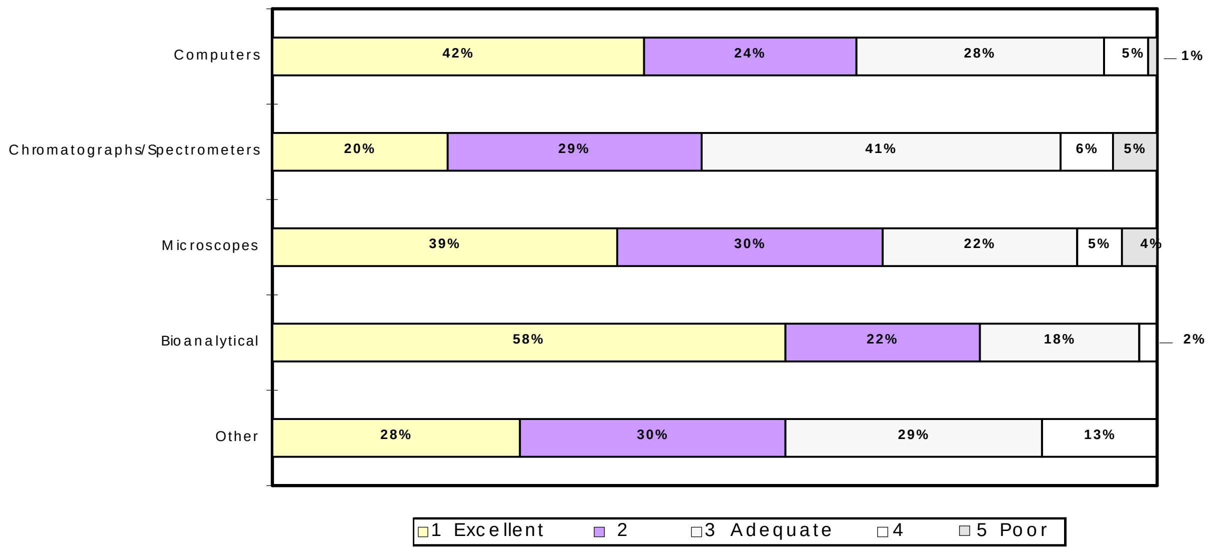
Note: Percents may not add up to 100 due to rounding.

Source: Academic Research Instruments and Instrumentation Needs in the Biological Sciences: 1994

The adequacy of the maintenance and repair support varied among the subfields of biology. Sixty-five percent of the instruments in microbiology received excellent maintenance and repair support in 1993; in pathology, only 22 percent of the instruments received excellent support for maintenance and repair. However, for both of these subfields, a minimum of 92 percent of the research instruments received at least adequate maintenance and repair support in 1993. (Figure 16)

The adequacy of maintenance and repair support for each of the major types of instruments is shown in Figure 17. Users of these instruments reported that they were quite satisfied with the level of maintenance support that they received. For example, 58 percent of the users of bioanalytical instruments reported that the maintenance/repair support was excellent. In no case did a majority of users of any major category of research instrument report that the maintenance/repair was less than adequate.

Figure 17. Adequacy of maintenance/repair received by biological research instruments, by instrument type: 1993



Note: Percents may not add up to 100 due to rounding.

Source: Academic Research Instruments and Instrumentation Needs in the Biological Sciences: 1994